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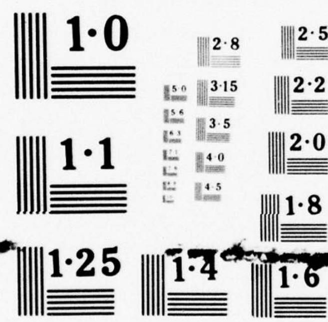

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FOREIGN TECHNOLOGY DIVISION

MOVEMENT OF A SOLID PROFILE
NEAR A SOLID BOUNDARY

by

B. S. Berkovskiy

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MOVEMENT OF A SOLID PROFILE NEAR A SOLID BOUNDARY

By: B. S. Berkovskiy

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Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

GREEK ALPHABET

Alpha	Α α *α*		Nu	Ν ν
Beta	Β β		Xi	Ξ ξ
Gamma	Γ γ		Omicron	Ο ο
Delta	Δ δ		Pi	Π π
Epsilon	Ε ε ϵ		Rho	Ρ ρ ϱ
Zeta	Ζ ζ		Sigma	Σ σ ς
Eta	Η η		Tau	Τ τ
Theta	Θ θ ϑ		Upsilon	Τ υ
Iota	Ι ι		Phi	Φ φ ϕ
Kappa	Κ ϰ κ *κ*		Chi	Χ χ
Lambda	Λ λ		Psi	Ψ ψ
Mu	Μ μ		Omega	Ω ω

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English
sin	sin
cos	cos
tg	tan
ctg	cot
sec	sec
cosec	csc
sh	sinh
ch	cosh
th	tanh
cth	coth
sch	sech
csch	csch
arc sin	$\sin^{-1}$
arc cos	$\cos^{-1}$
arc tg	$\tan^{-1}$
arc ctg	$\cot^{-1}$
arc sec	$\sec^{-1}$
arc cosec	$\csc^{-1}$
arc sh	$\sinh^{-1}$
arc ch	$\cosh^{-1}$
arc th	$\tanh^{-1}$
arc cth	$\coth^{-1}$
arc sch	sech^{-1}
arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

GRAPHICS DISCLAIMER

All figures, graphics, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

MOVEMENT OF A SOLID PROFILE NEAR A SOLID BOUNDARY

Studies on aerodynamic bodies moving near a solid or fluid boundary became very important after the development of aircraft which use the screen effect - air cushion aircraft, wing and ground effect vehicles, etc. This area of research is also of interest for creating vertical take-off and landing [VTOL] aircraft and low-wing aircraft, as well as for solving problems of changes in stability during movement near the ground.

The aerodynamic characteristics of an isolated wing with an infinite span moving near a solid boundary are determined in this report. Several analogous problems were considered in reports by M. V. Keldysh, Ye. Karafol', N. F. Sakharnyy, A. N. Panchenkov, etc.

We will consider steady flow about an arbitrary contour located near a solid rectilinear boundary.

Far in front of the contour, the flow rate is parallel to the solid wall, constant, and equal to v_0.

The problem is solved with the assumptions that the fluid is perfect and incompressible.

The motion is potential and steady:

$$\nabla\varphi = \bar{v}.$$

The continuity equation

$$\mathrm{div}\,\bar{v} = 0$$

results in the Laplace equation for potential ϕ

$$\Delta\phi = 0$$

with the boundary conditions of the continuous flow about contour C

$$\varphi_n = v_0 \cos(\widehat{n, x}) \quad (1.62)$$

and the absence of overflow to the solid wall

$$\varphi_y = 0. \quad (1.63)$$

Figure 2 shows a diagram of the problem and the coordinate system.

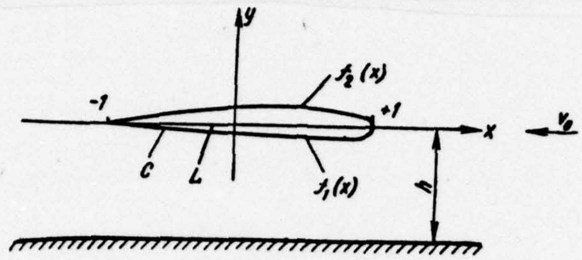

Fig. 2.

There are no perturbations infinitely far in front of the solid:

$$\nabla\varphi \to 0,$$
$$x \to +\infty.$$

In the linear approximation, condition (1.62) is satisfied on projection L of contour C on the x-axis. Then L is the given line of the velocity discontinuity.

We will introduce the complex flow potential

$$W(z) = -v_0 z + w(z),$$

where

$$w(z) = \varphi(x, y) + i\psi(x, y).$$

Then the boundary condition on the solid boundary will be

$$\operatorname{Im} w_z(z) = 0. \qquad (1.64)$$

We will introduce function $\Phi(z)$ with expression (1.64):

$$\Phi(z) = i w_z(z). \qquad (1.65)$$

$\Phi_+(x)$ and $\Phi_-(x)$ are the limiting values of the function in question $\Phi(z)$ when approaching projection L of the contour on the x-axis from above and below, respectively. Then the boundary conditions on projection L

$$\begin{aligned}\operatorname{Re}\Phi_-(x) &= -v_0 f_1'(x) = F_1(x),\\ \operatorname{Re}\Phi_+(x) &= -v_0 f_2'(x) = F_2(x).\end{aligned}$$

Using the transformations

$$\begin{aligned}&\operatorname{Re}\Phi_-(x) + \operatorname{Re}\Phi_+(x),\\ &\operatorname{Re}\Phi_-(x) - \operatorname{Re}\Phi_+(x),\end{aligned}$$

we will have

$$\left.\begin{aligned}\frac{\operatorname{Re}\Phi_-(x) + \operatorname{Re}\Phi_+(x)}{2} &= F_{\text{cp}},\\ \operatorname{Re}\Phi_-(x) - \operatorname{Re}\Phi_+(x) &= F_1(x) - F_2(x).\end{aligned}\right\} \qquad (1.66)$$

We will find function $\Phi(z)$ as follows

$$\Phi(z)=\frac{1}{2\pi}\int_{C}\left\{\gamma(s)\left[\frac{1}{z-s}+K_1(z,s)\right]+iq(s)\left[\frac{1}{z-s}+K_2(z,s)\right]\right\}ds, \tag{1.67}$$

where $K_1(z, s)$ and $K_2(z, s)$ are the analytical functions on projection L.

Proceeding to dimensionless values and omitting the nondimensionality index, we will write the limiting values of integral (1.67) when approaching segment L from above and below, respectively, as follows

$$\Phi_+(x) = \frac{i}{2}[\gamma(x) + iq(x)] +$$

$$+ \frac{1}{2\pi}\int_{-1}^{+1}\left\{\gamma(s)\left[\frac{1}{x-s} + K_1(x,s)\right] + iq(s)\left[\frac{1}{x-s} + K_2(x,s)\right]\right\}ds,$$

$$\Phi_-(x) = -\frac{i}{2}[\gamma(x) + iq(x)] +$$

$$+ \frac{1}{2\pi}\int_{-1}^{+1}\left\{\gamma(s)\left[\frac{1}{x-s} + K_1(x,s)\right] + iq(s)\left[\frac{1}{x-s} + K_2(x,s)\right]\right\}ds.$$

Using the limiting values of function $\Phi(z)$, obtained in expressions (1.66), we will obtain the integral equation of the problem for finding the intensity of the vortex layer $\gamma(s)$ and the expression for finding the normal velocity discontinuity which simulates the solidity of the profile:

$$\frac{1}{2\pi}\int_{-1}^{+1}\left\{\gamma(s)\left[\frac{1}{x-s}+\operatorname{Re}K_1(x,s)\right]-q(s)\operatorname{Im}K_2(x,s)\right\}ds=F_{cp}(x), \tag{I 68}$$

where

$$q(x)=F_1(x)-F_2(x), \tag{I.69}$$

$$F_{cp}(x)=-\frac{f_1'(x)+f_2'(x)}{2},$$

$$F_1(x)-F_2(x)=f_2'(x)-f_1'(x).$$

We will represent the integral equation obtained in a form more convenient for solution:

$$\frac{1}{2\pi}\int_{-1}^{+1}\left\{\gamma(s)\left[\frac{1}{x-s}+\operatorname{Re}K_1(x,s)\right]\right\}=F_{cp}(x)+F_h(x),$$

where

$$F_h(x)=\frac{1}{2\pi}\int_{-1}^{+1}q(s)\operatorname{Im}K_2(x,s)\,ds.$$

Functions K_1 and K_2 are determined with condition (1.64) and are represented as follows

$$K_1(x, s) = -\frac{1}{(x-s)-i4\bar{h}},$$
$$K_2 = -K_1. \qquad (1.70)$$

We will find the solution to the integral equation for $\gamma(s)$ as follows

$$\gamma(s) = \gamma_1(s) + \gamma_2(s),$$

where γ_1 corresponds to the solution to the equation at $F_{\bar{\eta}}(x) = 0$, and γ_2 corresponds to the solution of the equation at $F_{cp}(x) = 0$. In this case, the equation for the problem is broken down into two independent integral equations:

$$\frac{1}{2\pi}\int_{-1}^{+1}\gamma_j(s)\left[\frac{1}{x-s}+\operatorname{Re}K_1(x,s)\right]ds=N_j\qquad (j=1,2),\quad (1.71)$$

where

$$N_1=F_{cp}(x),$$
$$N_2=F_{\bar{h}}(x).$$

We will find the solution to $\gamma_j(s)$ in the form of series by a certain small parameter limited by τ^7:

$$\gamma_1(s)=\gamma_{01}+\gamma_{11}\tau^2+\gamma_{21}\tau^4+\gamma_{31}\tau^6+\ldots,$$
$$\gamma_2(s)=\gamma_{12}\tau+\gamma_{22}\tau^3+\gamma_{32}\tau^5+\gamma_{42}\tau^7+\ldots.\qquad (1.72)$$

In this case, we use the τ-parameter

$$\tau=\sqrt{4\bar{h}^2+1}-2\bar{h},$$

obtained by A. N. Panchenkov [25, 27] from expression

$$4\bar{h}=\frac{1}{\tau}-\tau. \tag{1.73}$$

First we will solve the equation for $\gamma_1(s)$. Using expression (1.73), we will have

$$K_2=i\,[(\tau+\tau^3+\tau^5+\tau^7+\ldots)-(x-s)^2(\tau^3+3\tau^5+6\tau^7+\ldots)+ \\ +(x-s)^4(\tau^5+5\tau^7+\ldots)-(x-s)^6(\tau^7+\ldots)]+[(x-s)(\tau^2+ \\ +2\tau^4+3\tau^6+\ldots)-(x-s)^3(\tau^4+4\tau^6+\ldots)+ \\ +(x-s)^5(\tau^6+\ldots)]. \tag{1.74}$$

Using equation (1.70), this makes it possible to express

$$\operatorname{Re}K_1(x,s)=\sum_{m=1}^{3}K_{m1}\tau^{2m},$$

where

$$K_{11}=-(x-s),$$

$$K_{21}=-[2(x-s)-(x-s)^3],$$

$$K_{31}=-[3(x-s)-4(x-s)^3+(x-s)^5].$$

Thus, equation (1.71) assumes the form:

$$\int_{-1}^{+1} \gamma_1(s)\left[\frac{1}{x-s}+\sum_{m=1}^{3} K_{m1}\tau^{2m}\right] ds = -2\pi F_{cp}(x)$$

or

$$\int_{-1}^{+1} \gamma_1(s)\frac{1}{x-s}\, ds = -2\pi F_{cp}(x) - \int_{-1}^{+1} \gamma_1(s) \sum_{m=1}^{3} K_{m1}\tau^{2m} ds. \quad (1.75)$$

Using expression $\gamma_1(s)$ from (1.72) and equating the terms at identical exponents of τ on the right and left sides of equation (1.75), we will have the series of singular equations

$$\int_{-1}^{+1} \frac{\varphi(s)}{x-s} ds = \psi(s),$$

whose solutions, limited at point x = -1, are determined by the Cauchy interval transform:

$$\varphi(x) = \frac{1}{\pi^2} \sqrt{\frac{1+x}{1-x}} \int_{-1}^{+1} \sqrt{\frac{1-s}{1+s}} \frac{\psi(s)}{x-s} ds, \tag{1.76}$$

$$\int_{-1}^{+1} \frac{\gamma_{01}(s)}{x-s} ds = -2\pi F_{cp}(x),$$

$$\int_{-1}^{+1} \frac{\gamma_{11}(s)}{x-s} ds = -\int_{-1}^{+1} K_{11}(s)\gamma_{01}(s) ds,$$

$$\int_{-1}^{+1} \frac{\gamma_{21}(s)}{x-s} ds = -\int_{-1}^{+1} [K_{11}(s)\gamma_{11}(s) + K_{21}(s)\gamma_{01}(s)] ds,$$

$$\int_{-1}^{+1} \frac{\gamma_{31}(s)}{x-s} ds = -\int_{-1}^{+1} [K_{11}(s)\gamma_{21}(s) + K_{21}(s)\gamma_{11}(s) + K_{31}(s)\gamma_{01}(s)] ds.$$

The last three equations are represented by the recurrent formula

$$\int_{-1}^{+1} \frac{\gamma_{n1}}{x-s}\,ds = -\int_{-1}^{+1} \sum_{m=1}^{3} K_{m1}\gamma_{(n-m)1}\,ds.$$

Representing the middle line of the profile in the form of small arcs with a central angle of 2β, we will have

$$F_{cp}(x) = \alpha - \beta x.$$

Then the computation of γ_{n1} results in

$$\gamma_{01} = 2\sqrt{\frac{1+x}{1-x}}[(\alpha+\beta)-\beta_x],$$

$$\gamma_{11} = 2\sqrt{\frac{1+x}{1-x}}\left[\left(\alpha+\frac{1}{2}\beta\right)\left(\frac{3}{2}-x\right)-\frac{1}{4}\beta\right],$$

$$\gamma_{21} = 2\sqrt{\frac{1+x}{1-x}}\left[\left(\frac{9}{8}\alpha+\frac{5}{8}\beta\right)+\left(\frac{1}{2}\alpha-\frac{5}{8}\beta\right)x-\right.$$
$$\left.-\left(\frac{5}{2}\alpha+\frac{1}{2}\beta\right)x^2+\left(\alpha+\frac{1}{2}\beta\right)x^3\right],$$

$$\gamma_{31} = 2\sqrt{\frac{1+x}{1-x}}\left[\left(\frac{15}{16}\alpha+\frac{9}{16}\beta\right)+\left(\frac{9}{8}\alpha-\frac{9}{16}\beta\right)x-\right.$$
$$-\left(\frac{5}{4}\alpha+\frac{3}{4}\beta\right)x^2-\left(3\alpha-\frac{3}{4}\beta\right)x^3+$$
$$\left.+\left(\frac{7}{2}\alpha+\frac{1}{2}\beta\right)x^4-\left(\alpha+\frac{1}{2}\beta\right)x^5\right].$$

We will proceed to finding the solution for γ_2. At j = 2, equation (1.71) is written as follows

$$\frac{1}{2\pi}\int_{-1}^{+1}\gamma_2(s)\left[\frac{1}{x-s}+\operatorname{Re}K_1(x,s)\right]ds=\frac{1}{2\pi}\int_{-1}^{+1}q(s)\operatorname{Im}K_2(x,s)\,ds=F_{\bar{h}}(x).$$

Using expression (1.74), we will represent $F_{\bar{h}}$ as follows

$$F_{\bar{h}}(x)=\sum_{n=1,3,\ldots}^{7}F_{\bar{h}n}(x)\,\tau^n.$$

In this case, function q(s), which is part of the expression for $F_{\bar{h}}(x)$ - the intensity of the sources simulating the normal velocity discontinuity - adheres to the condition

$$\int_C q(s)\,ds=0, \qquad (1.77)$$

i.e., the nonpenetrability of the profile makes it necessary to return the sum of the abundances of the sources to zero. This places a limit on the form of function q(s).

Condition (1.77) satisfies the function

$$q(s)=\sqrt{1-s^2}\,(a_0 s+a_1 s^3+a_2 s^5+\ldots). \quad (1.78)$$

In this case, function $F_{\bar{h}n}$ will be

$$F_{\bar{h}1}=0,$$

$$F_{\bar{h}3}=\left[x\left(\frac{1}{8}a_0+\frac{1}{16}a_1+\frac{5}{128}a_2\right)\right],$$

$$F_{\bar{h}5}=\left|x\left(\frac{1}{4}a_0+\frac{7}{64}a_1+\frac{1}{16}a_2\right)-x^3\left(\frac{1}{4}a_0+\frac{1}{8}a_1+\frac{5}{64}a_2\right)\right|,$$

$$F_{\bar{h}7}=\left[x\left(\frac{31}{128}a_0+\frac{17}{256}a_1+\frac{23}{1024}a_2\right)-x^3\times\right.$$

$$\left.\times\left(\frac{5}{8}a_0+\frac{15}{64}a_1+\frac{15}{128}a_2\right)+x^5\left(\frac{3}{8}a_0+\frac{3}{16}a_1+\frac{15}{128}a_2\right)\right].$$

Thus, we will have

$$\frac{1}{2\pi}\int_{-1}^{+1}\gamma_2(s)\frac{1}{x-s}ds=\sum_{n=1,3,\ldots}^{7}F_{\bar{h}n}(x)\tau^n-\frac{1}{2\pi}\int_{-1}^{+1}\gamma_2(s)\sum_{m=1}^{3}K_{m1}\tau^{2m}.$$

Using the expression for $\gamma_2(s)$ from (1.72) and equating the coefficients at identical exponents, like before, we will obtain a series of singular equations whose solution is in the class of functions limited at point $x = -1$:

$$\frac{1}{2\pi}\int_{-1}^{+1}\frac{\gamma_{12}(s)}{x-s}\,ds=0,$$

$$\frac{1}{2\pi}\int_{-1}^{+1}\frac{\gamma_{22}(s)}{x-s}\,ds=F_{\bar{h}3}(x),$$

$$\frac{1}{2\pi}\int_{-1}^{+1}\frac{\gamma_{32}(s)}{x-s}\,ds=F_{\bar{h}5}(x)-\frac{1}{2\pi}\int_{-1}^{+1}[K_{11}(x,s)\gamma_{22}(s)+K_{21}(x,s)\gamma_{12}(s)]\,ds,$$

$$\frac{1}{2\pi}\int_{-1}^{+1}\frac{\gamma_{42}(s)}{x-s}\,ds=F_{\bar{h}7}(x)-\frac{1}{2\pi}\int_{-1}^{+1}[K_{11}(x,s)\gamma_{32}(s)+K_{21}(x,s)\gamma_{22}(s)+$$
$$+K_{31}(x,s)\gamma_{12}(s)]\,ds.$$

Using formula (1.76), we will have

$$\gamma_{12}=0,$$

$$\gamma_{22}=2(1-x)\sqrt{\frac{1+x}{1-x}}\left(\frac{1}{8}a_0+\frac{1}{16}a_1+\frac{5}{128}a_2\right),$$

$$\gamma_{32}=2(1-x)\sqrt{\frac{1+x}{1-x}}\left|\left(\frac{3}{16}a_0+\frac{5}{64}a_1+\frac{11}{256}a_2\right)-\right.$$
$$\left.-\left(\frac{1}{4}a_0+\frac{1}{8}a_1+\frac{5}{64}a_2\right)x^2\right|.$$
$$\gamma_{42}=2(1-x)\sqrt{\frac{1+x}{1-x}}\left|\left(\frac{23}{128}a_0+\frac{17}{256}a_1+\frac{35}{1024}a_2\right)-\right.$$
$$\left.-\left(\frac{1}{2}a_0+\frac{11}{64}a_1+\frac{5}{64}a_2\right)x^2+\left(\frac{3}{8}a_0+\frac{3}{16}a_1+\frac{15}{128}a_2\right)x^4\right|.$$

Having the solution to $\gamma_1(x)$ and $\gamma_2(x)$, we will obtain the total solution

$$\gamma(x)=\gamma_{01}+\gamma_{11}\tau^2+\gamma_{21}\tau^4+\gamma_{31}\tau^6+\gamma_{12}\tau+\gamma_{22}\tau^3+\gamma_{32}\tau^5+\gamma_{42}\tau^7.$$

which makes it possible to compute the lift of a wing with an infinite span near a screen:

$$P = \varrho a v_0^2 \int_{-1}^{+1} \gamma(x)\, dx.$$

Using the fact that $\gamma = \gamma_1 + \gamma_2$, we will represent the lift in the form of the two components of a thin wing and the solidity of the profile:

$$P = P_1 + P_2$$

The calculation of P_i results in

$$P_1 = 2\varrho a v_0^2 \pi \left\{ \left(\alpha + \frac{1}{2}\beta \right) + \left[\left(\alpha + \frac{1}{2}\beta \right) - \frac{1}{4}\beta \right] \tau^2 + \left[\frac{1}{2}\alpha + \frac{1}{4}\beta \right] \tau^4 + \right.$$

$$\left. + \left[\frac{3}{4}\alpha - \frac{7}{32}\beta \right] \tau^6 \right\}. \qquad (1.79)$$

$$P_2 = 2\varrho a v_0^2 \pi \left\{ \frac{1}{2} \left(\frac{1}{8} a_0 + \frac{1}{16} a_1 + \frac{5}{128} a_2 \right) \tau^3 + \left(\frac{1}{16} a_0 + \frac{3}{128} a_1 + \right. \right.$$

$$\left. \left. + \frac{3}{256} a_2 \right) \tau^5 + \left(\frac{13}{256} a_0 + \frac{29}{512} a_1 + \frac{15}{1024} a_2 \right) \tau^7 \right\}. \qquad (1.80)$$

Proceeding to the dimensionless form, we will have

$$\bar{\gamma}_1 = \left[1 + \left(1 - \frac{\frac{1}{4}\beta}{\alpha_0 + \alpha_k} \right) \tau^2 + \frac{1}{2}\tau^4 + \frac{3}{4} \left(1 - \frac{\frac{19}{24}\beta}{\alpha_0 + \alpha_k} \right) \tau^6 \right], \quad (1.81)$$

$$\bar{\gamma}_2 = \frac{1}{16}\left[\frac{\left(a_0 + \frac{1}{2}a_1 + \frac{5}{16}a_2\right)}{\alpha_0 + \alpha_k}\tau^3 + \frac{\left(a_0 + \frac{3}{8}a_1 + \frac{3}{16}a_2\right)}{\alpha_0 + \alpha_k}\tau^5 + \right.$$
$$\left. + \frac{\frac{1}{16}\left(13a_0 + \frac{29}{2}a_1 + \frac{15}{4}a_2\right)}{\alpha_0 + \alpha_k}\tau^7\right], \qquad (1.82)$$

where

$$\alpha_0 = \alpha, \quad \alpha_k = \frac{1}{2}\beta.$$

We can express function $\bar{\gamma}_1$ as

$$\bar{\gamma}_1 = \psi + \frac{\varkappa_1}{\alpha_0 + \alpha_k},$$

where

$$\psi = 1 + \tau^2 + \frac{1}{2}\tau^4 + \frac{3}{4}\tau^6 + \ldots$$

characterizes the change in the angle of slope of dependence $C_y(\alpha)$ near the boundary, while function

$$\varkappa_1 = -\left(\frac{1}{4}\beta\tau^2 + \frac{19}{32}\beta\tau^6 + \ldots\right),$$

i.e.,

$$\varkappa_1 = f(\beta, \tau^{2,6,10,\ldots}).$$

Function $\bar{\gamma}_2$ can be expressed as

$$\bar{\gamma}_2 = \frac{\varkappa_2}{a_0 + a_k},$$

where

$$\varkappa_2 = \frac{1}{16}\left[\left(a_0 + \frac{1}{2}a_1 + \frac{5}{16}a_2\right)\tau^3 + \left(a_0 + \frac{3}{8}a_1 + \frac{3}{16}a_2\right)\tau^5 + \right.$$
$$\left. + \frac{1}{16}\left(13a_0 + \frac{29}{2}a_1 + \frac{15}{4}a_2\right)\tau^7\right].$$

Then

$$\bar{\gamma} = \frac{P_{\bar{h}}}{P_{\infty}} = \psi + \frac{\varkappa}{\alpha_0 + \alpha_k},$$

where

$$\varkappa = \varkappa_1 + \varkappa_2.$$

In the common case, e.g., of a thin ellipse,

$$y = \pm b\sqrt{1 - \frac{x^2}{a^2}}.$$

Proceeding to relative values, at a = 1 we will have

$$f_{2,1} = y_{2,1} = \pm \delta \sqrt{1 - x^2}. \qquad (1.83)$$

where $\delta \leq 1$ is the relative thickness of the solid.

Since

$$f'_{2,1} = \pm \frac{\delta_x}{\sqrt{1 - x^2}},$$

then, using (1.69) and (1.83), we will have

$$q(x) = \frac{2\delta x}{\sqrt{1 - x^2}}. \qquad (1.84)$$

Equating (1.84) and (1.78)

$$\frac{2\delta x}{\sqrt{1 - x^2}} = \sqrt{1 - x^2}\,(a_0 + a_1 x^2 + a_2 x^4 + \ldots).$$

we will find the relationship between the shape of the profile and coefficients a_i: at $x_1 = 0$, $a_0 = 0$; at $x_2 = 0.7$, $a_1 = 8.95\ \delta$; and at $x_3 = 0.95$, $a_2 = 34.6\ \delta$. Then function $\varkappa_2$ assumes the form

$$\varkappa_2 = \delta \frac{(6{,}345\tau^3 + 3{,}135\tau^5 + 0{,}0125\tau^7)}{16}.$$

Thus, we obtained functions $\psi, \varkappa_1(\alpha_0), \varkappa_2(\delta)$, making it possible to compute the aerodynamic characteristics of a profile moving near a screen with consideration of its geometry - curvature and thickness.

In the common case of a thin ellipse, the results of the solution are given on the graph in the form of curves $\psi, \left|\frac{\varkappa_1}{\beta}\right|; \left|\frac{\varkappa_2}{\delta}\right|$ with relative height $\bar{h}$ (Fig. 3).

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